THE EFFECT OF MICROSTRUCTURAL HETEROGENEITY ON DUCTILE FAILURE

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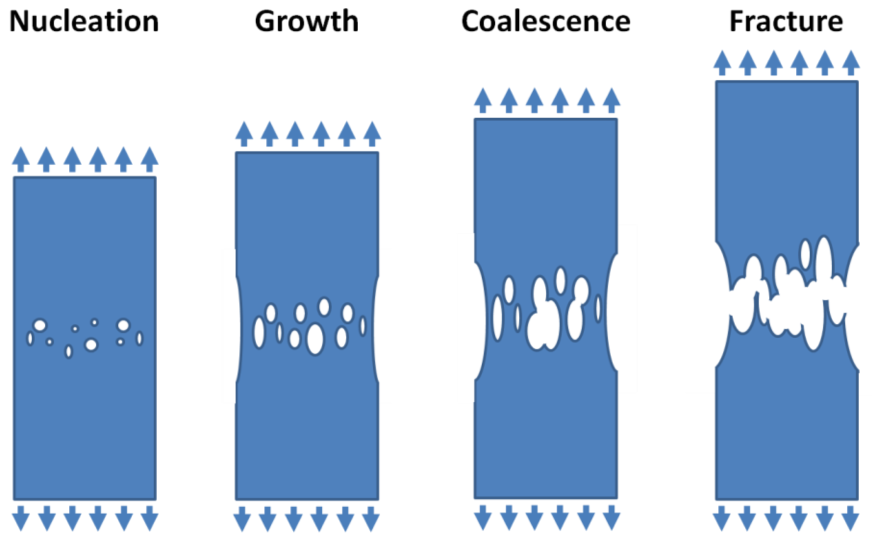
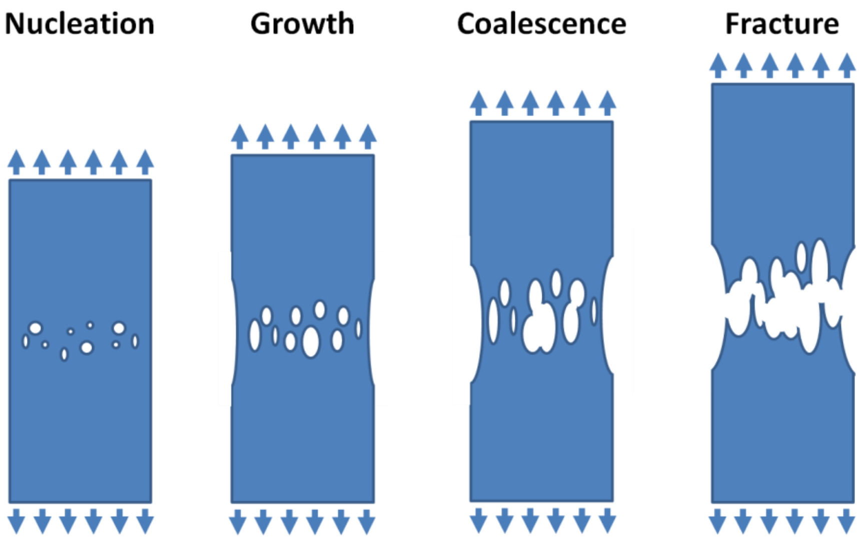
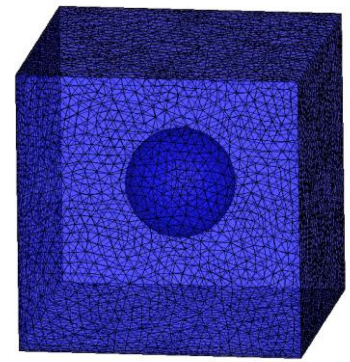
DUCTILE FAILURE

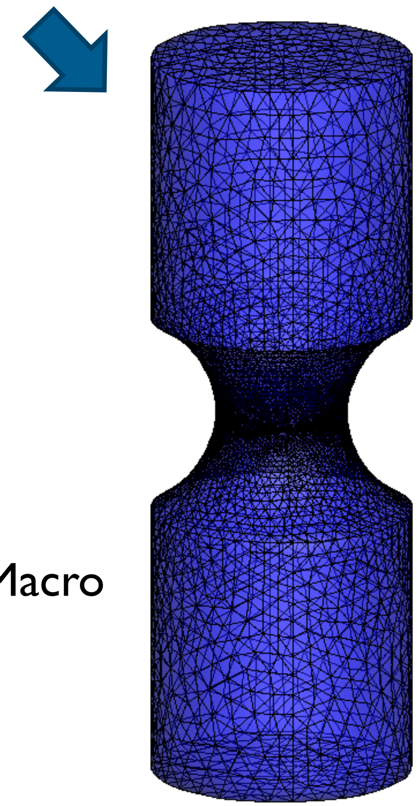


THE TWO SCALE PROBLEM





Micro

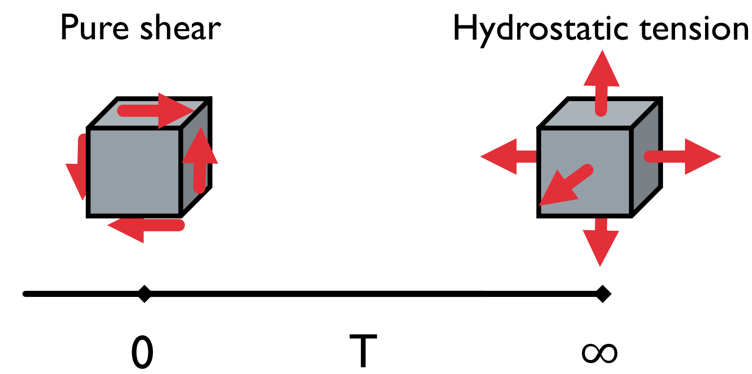


Macro

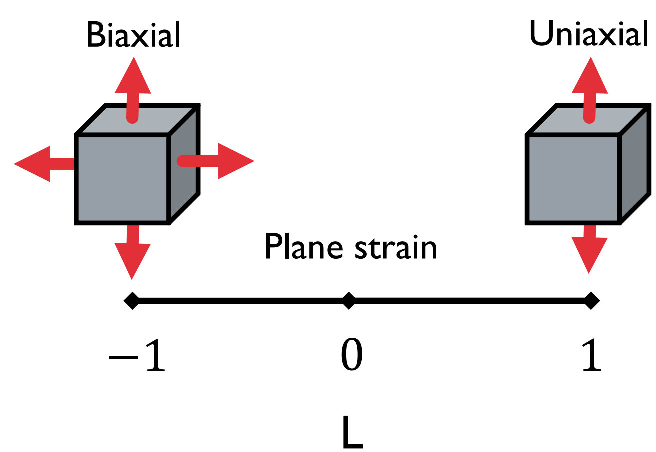
- Large-scale phenomenon controlled by micro-scale features
- We aim to capture two effects:
  - Variability in loading (micro-scale)
  - Variability in initial microstructure

VARIABILITY IN LOADING (MICRO-SCALE)

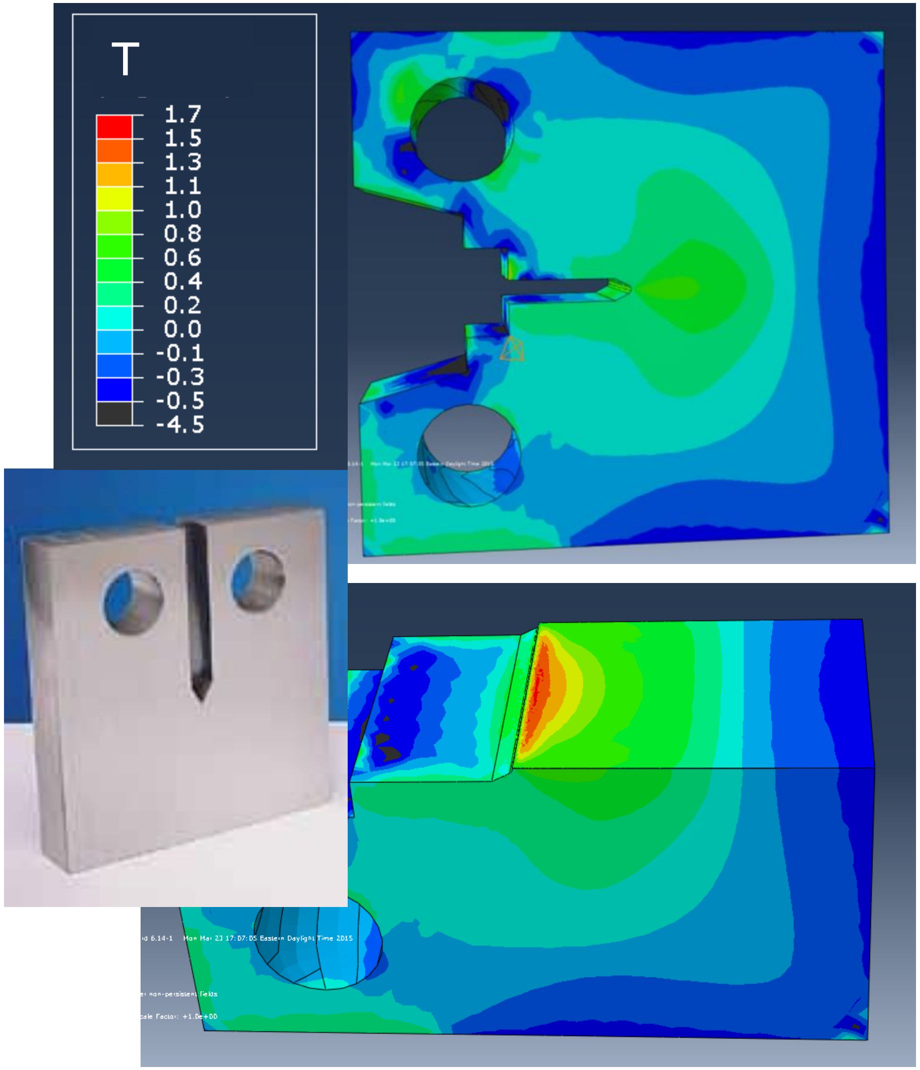
- Here loading is defined by 2 parameters
  - Triaxiality
    - $T = \frac{\sigma_h}{\sigma_e}$

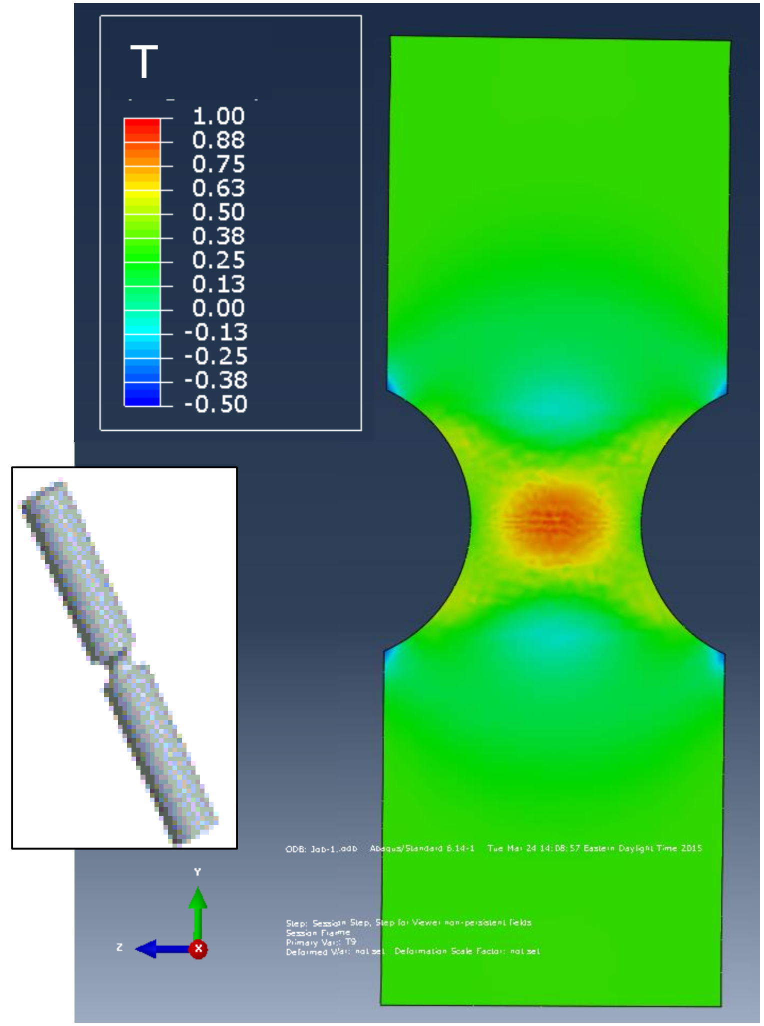


  - Lode Parameter
    - $L = \frac{27 J_3}{2\sigma_e^3}$

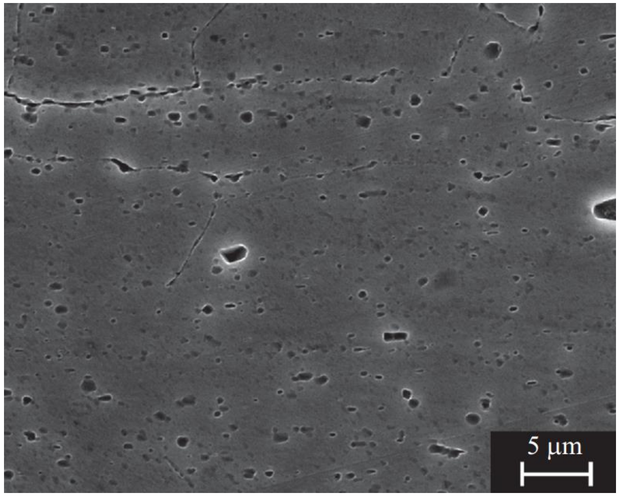


VARIABILITY IN LOADING (MICRO-SCALE)

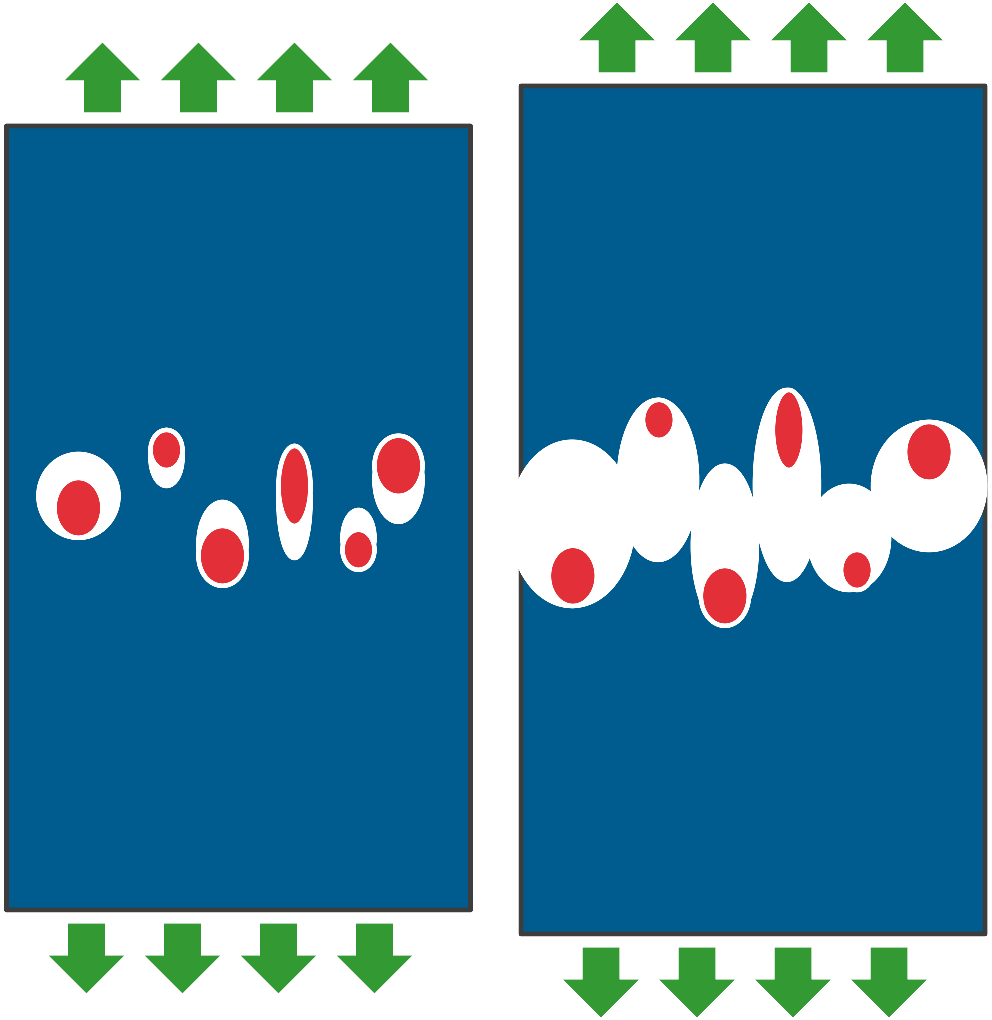




VARIABILITY IN MICROSTRUCTURE



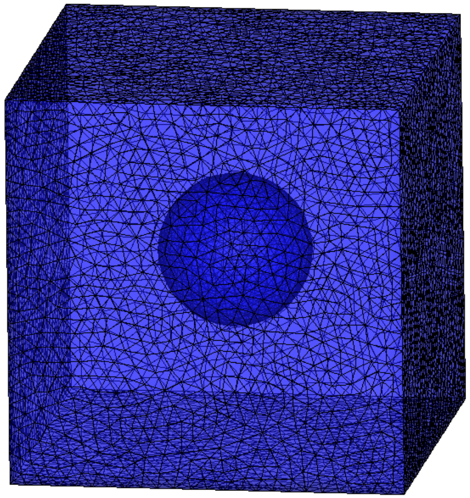
Chen and Lai (2014)

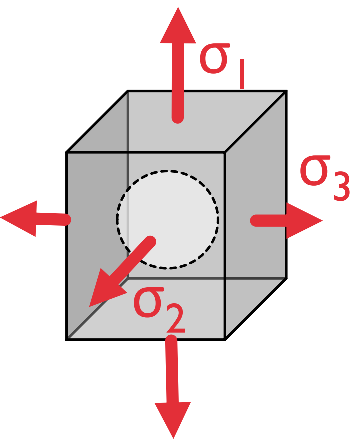


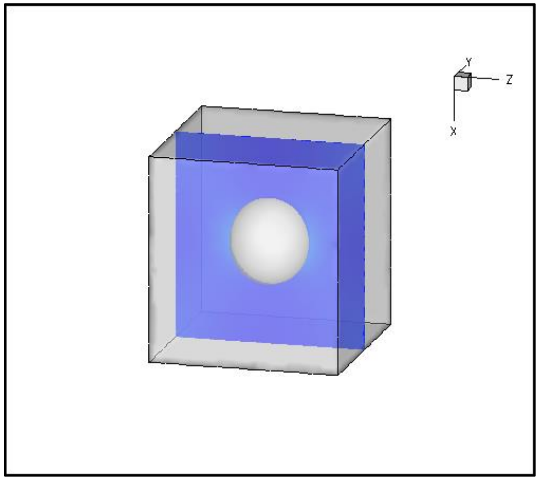
- Assume second phase particles act as voids
- Assume local porosity to be the defining microstructural feature

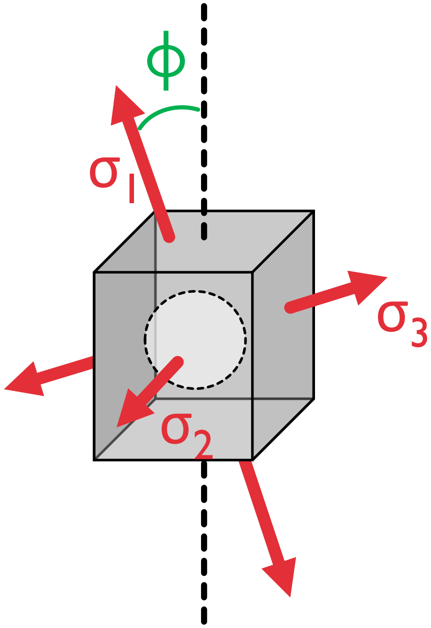
THE MODEL: MICRO-SCALE

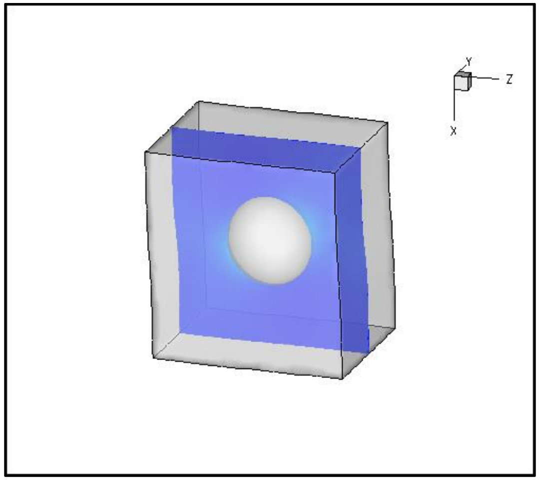
- 3D FEM
- Initial porosity (f_0) defines geometry
- T and L define the loading ratios: $\frac{\sigma_2}{\sigma_1}$ and $\frac{\sigma_3}{\sigma_1}$
- Allow for different localization modes











THE MODEL: CONTINUUM-SCALE

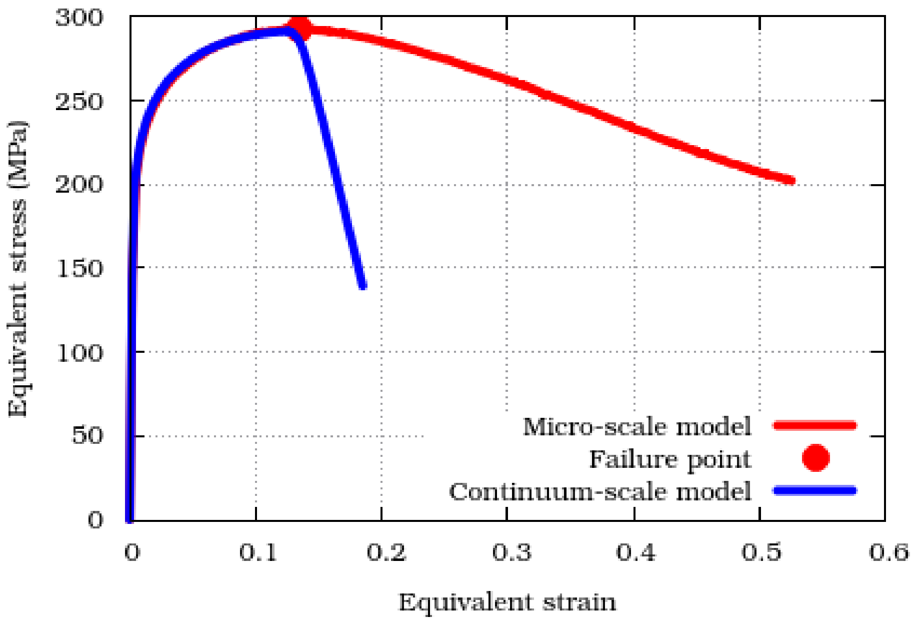
$$\Phi = \left(\frac{\bar{\sigma}}{\sigma_y}\right)^2 + 2q_1 f^* \cosh\left(\frac{3}{2} q_2 \frac{\sigma_h}{\sigma_y}\right) - \left(1 + (q_1 f^*)^2\right)$$

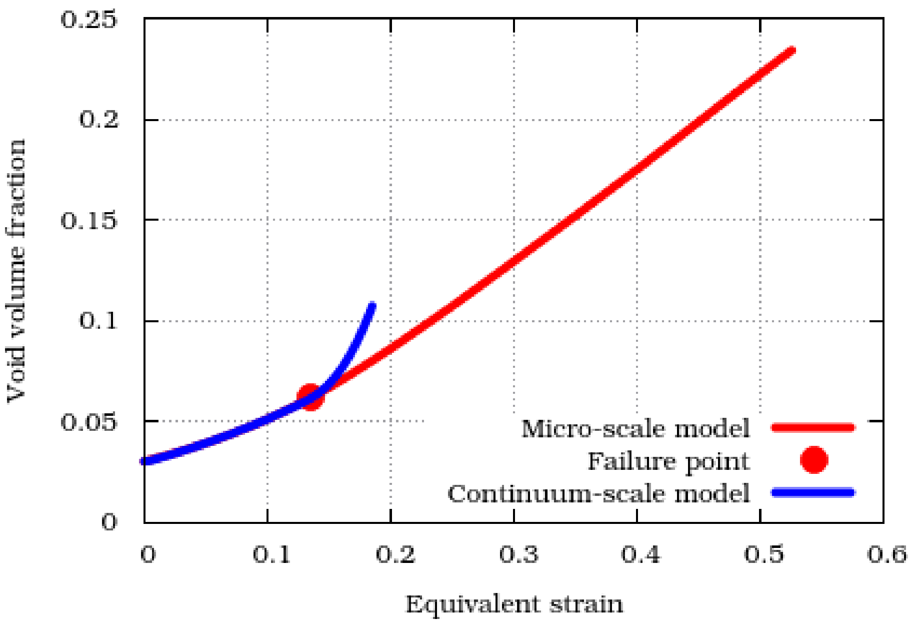
$$f^* = \begin{cases} f & : f \leq f_c \\ f_c + \kappa(f - f_c) & : f > f_c \end{cases}$$

q_1

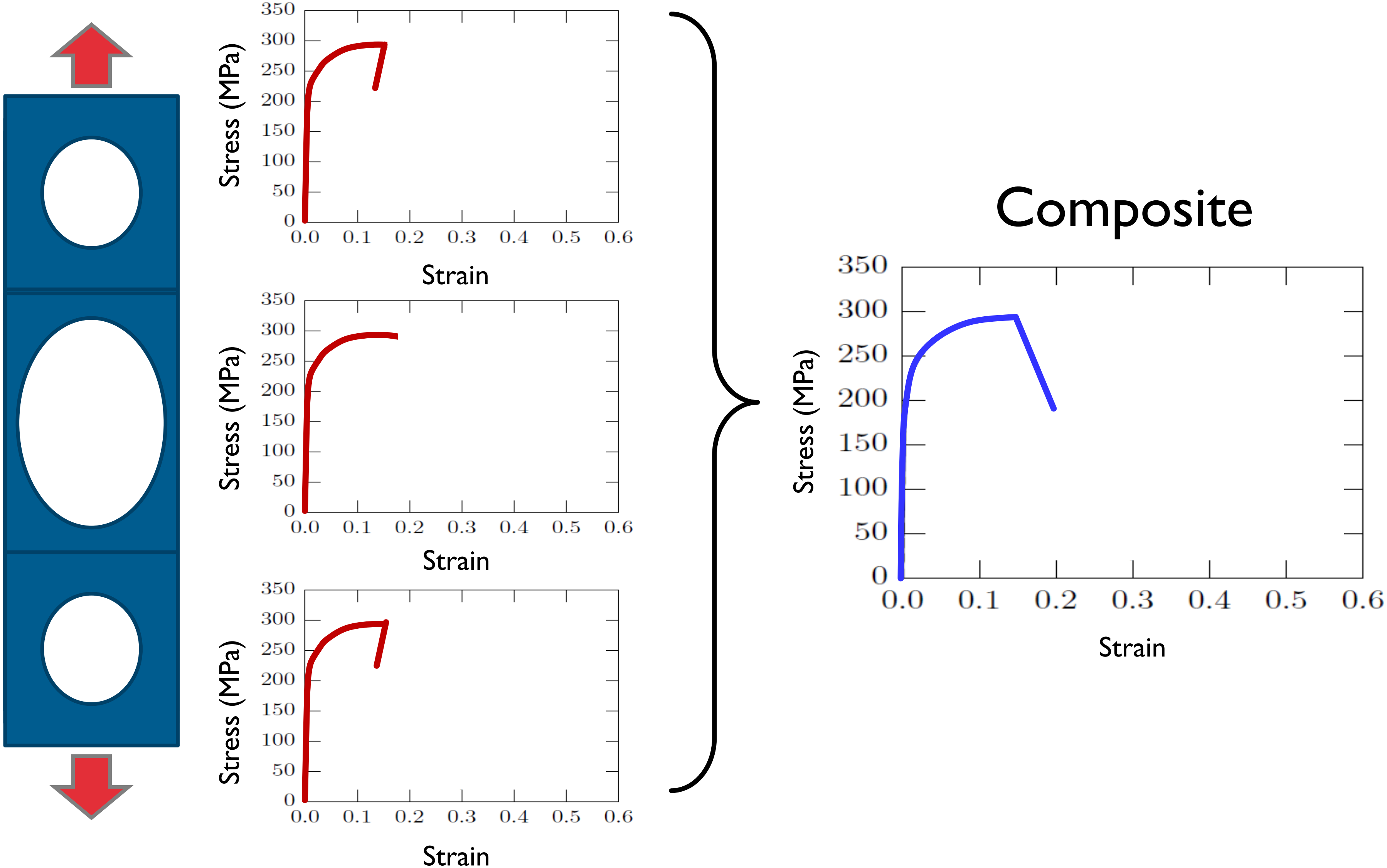
q_2

f_c



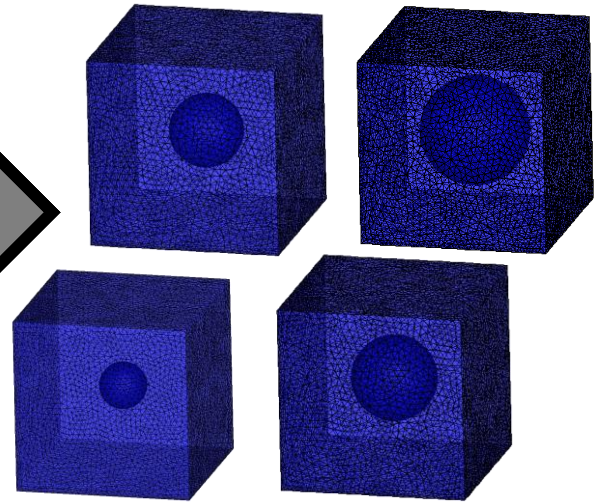


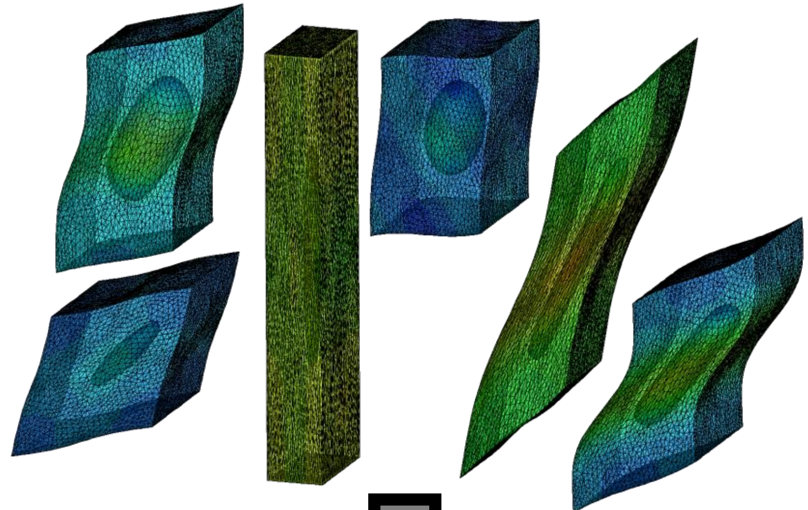
POST-FAILURE RESPONSE



RECAP ON MECHANICAL RESPONSE

Given:
f_0, T, L

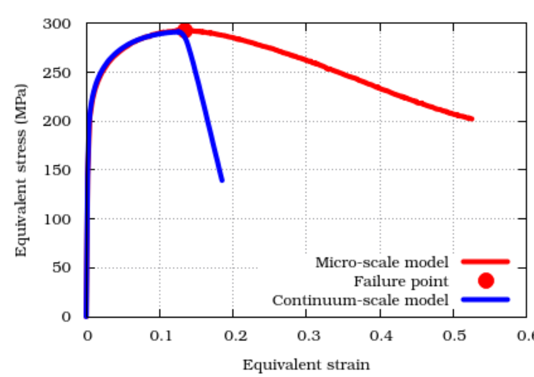


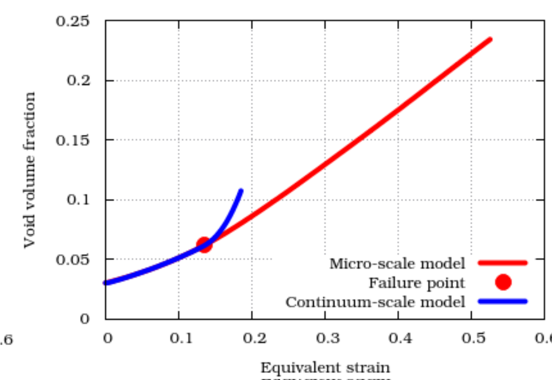


Response $= f(microstructure, loading)$

$$q_1(f_0, T, L)$$
$$q_2(f_0, T, L)$$
$$f_c(f_0, T, L)$$

$$q_1$$
$$q_2$$
$$f_c$$

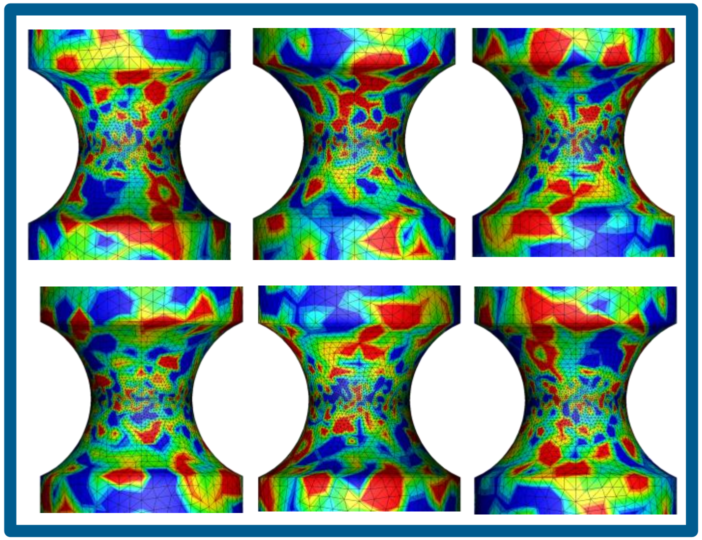


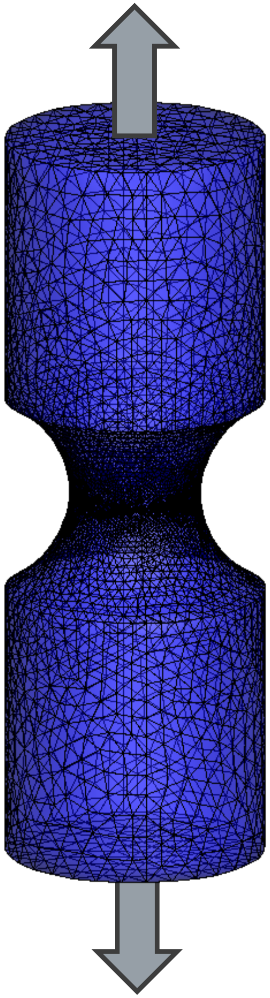


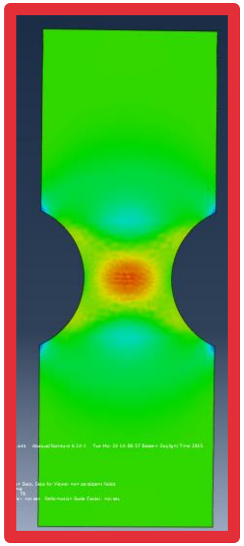
UNCERTAINTY QUANTIFICATION

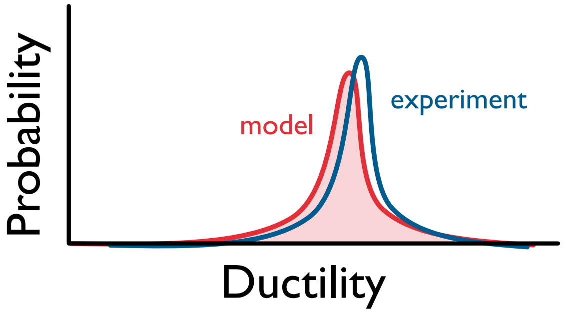
Response $= f\,(microstructure, loading)$

$$
\begin{array}{l}
q_1(f_0, T, L) \\
q_2(f_0, T, L) \\
f_c(f_0, T, L)
\end{array}
$$

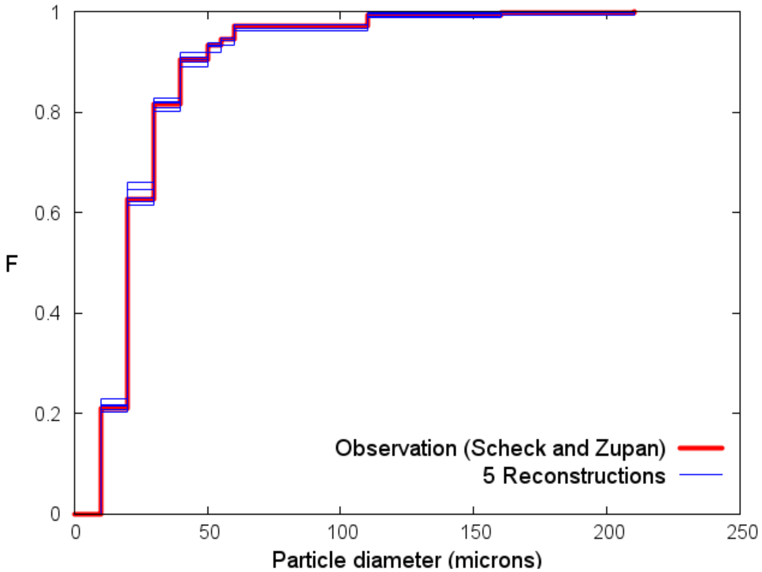


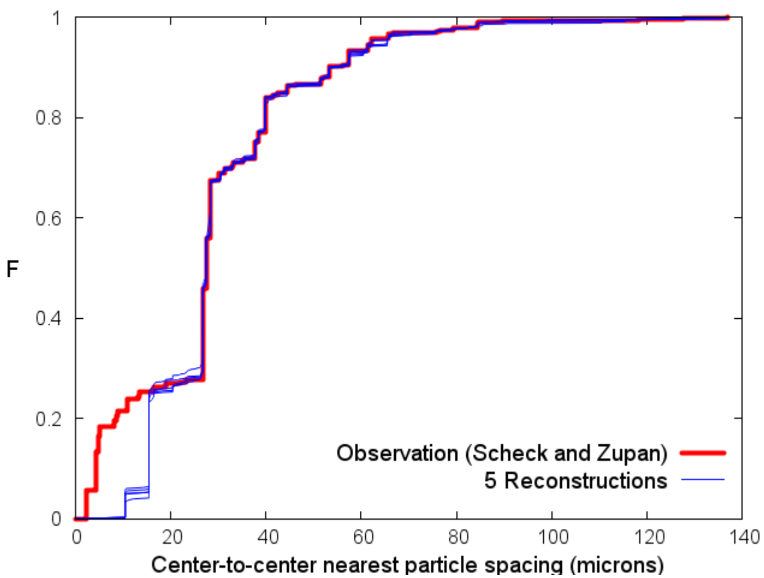




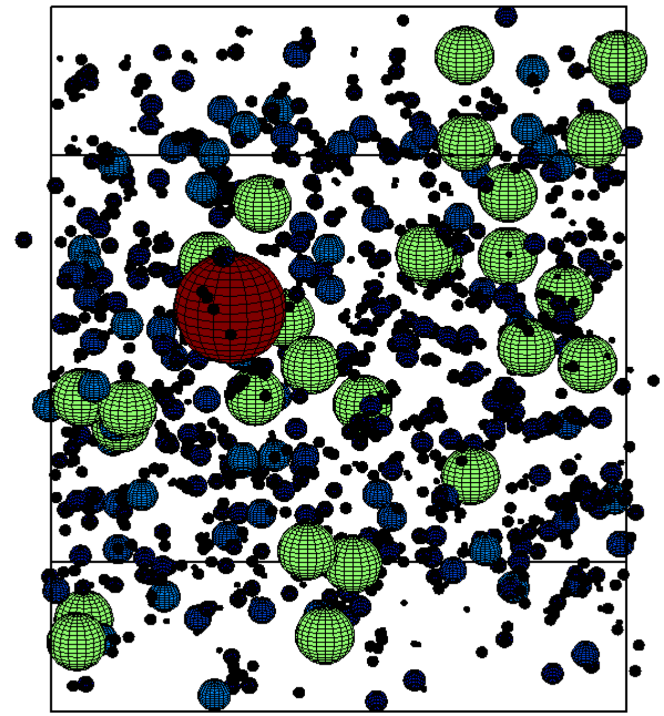


CREATION OF REPRESENTATIVE MICROSTRUCTURES



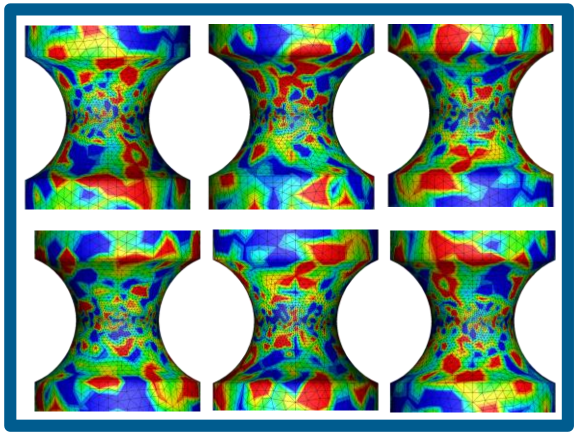


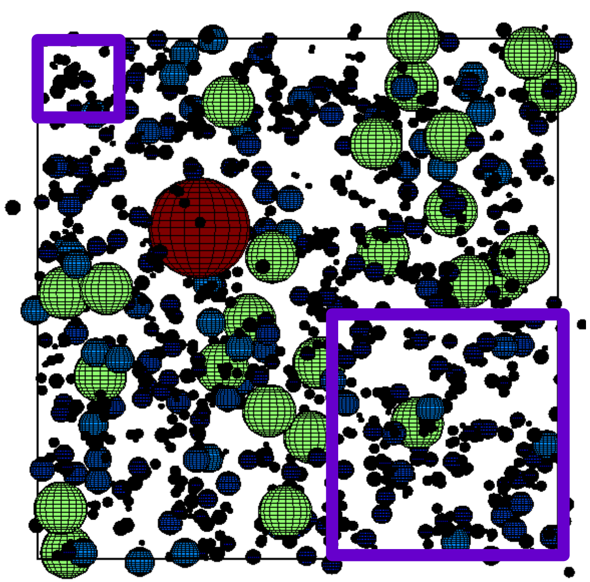
Average particle volume fraction = 3%

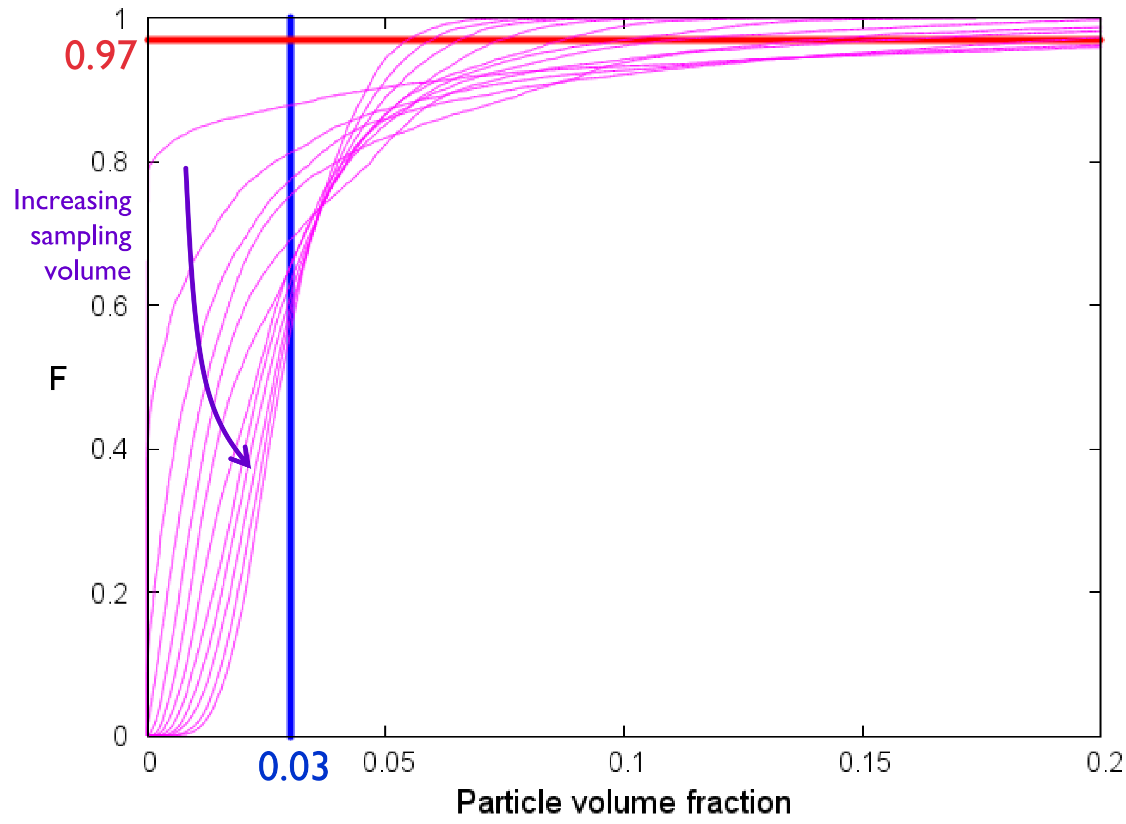


QUERY RECONSTRUCTIONS FOR NEW STATISTICS

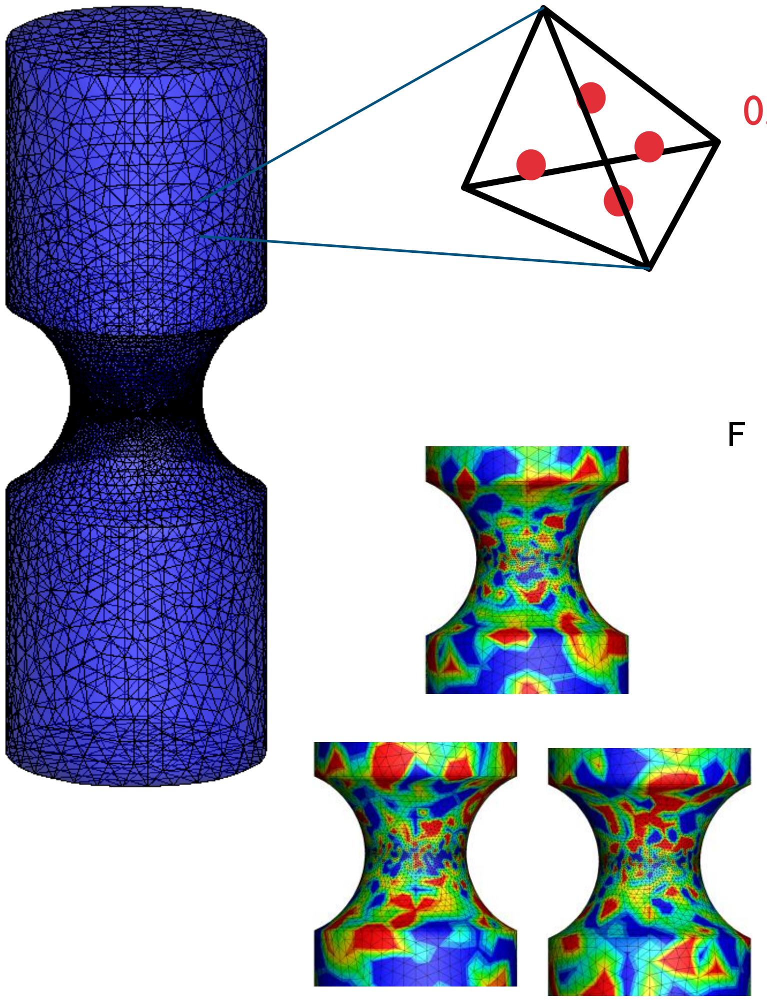
Looking for statistics on particle volume fraction (f_0)
-dependent upon sampling volume!

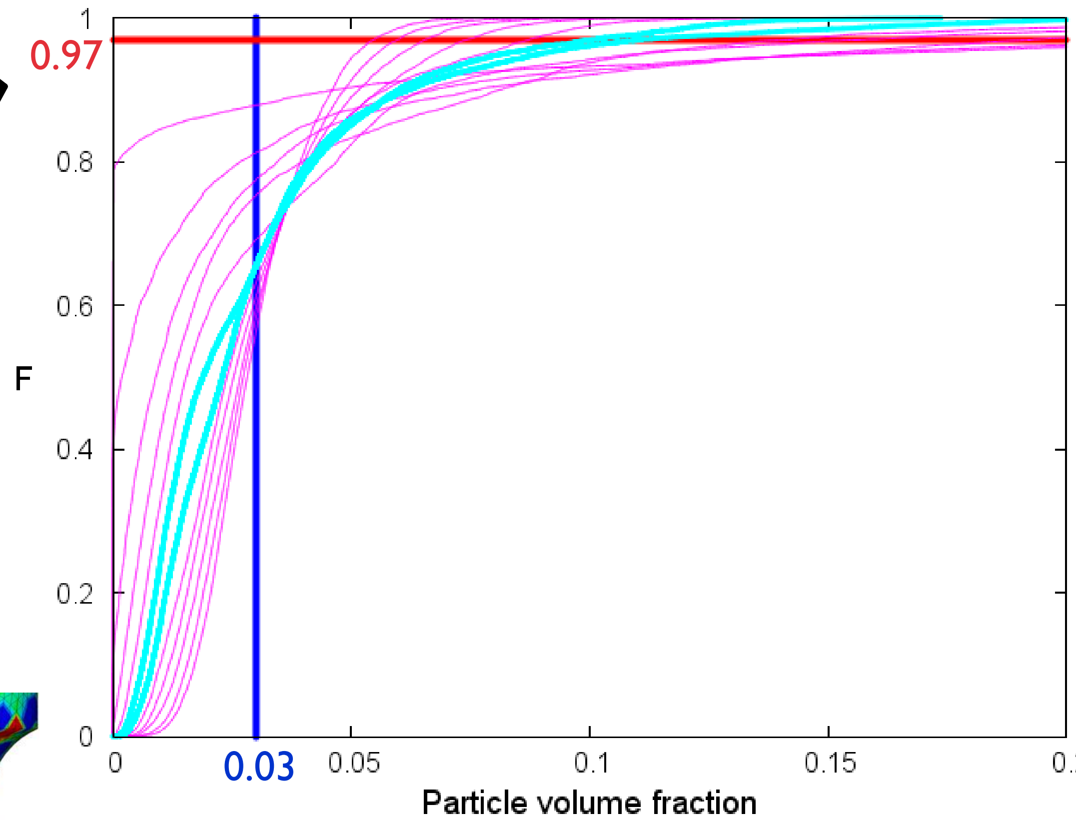




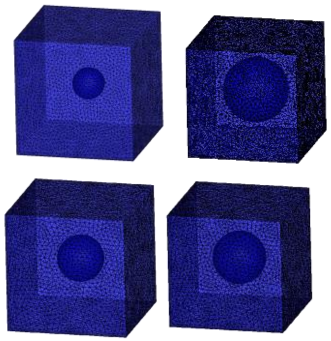


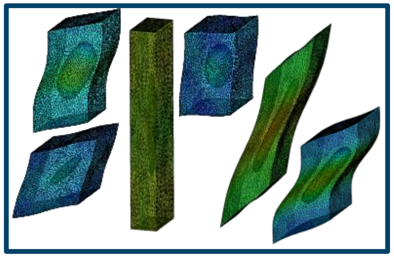
ASSIGNING LOCAL MICROSTRUCTURE



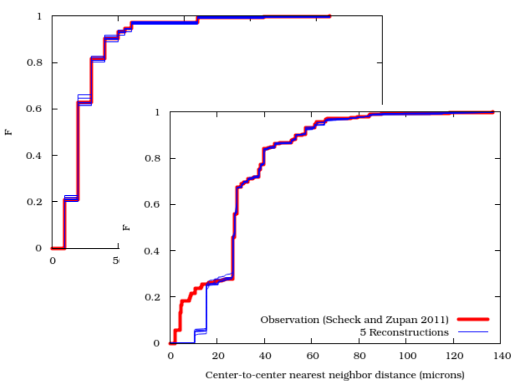


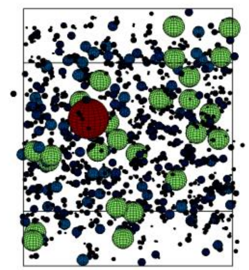
RECAP ON SEEDING RANDOM MICROSTRUCTURES

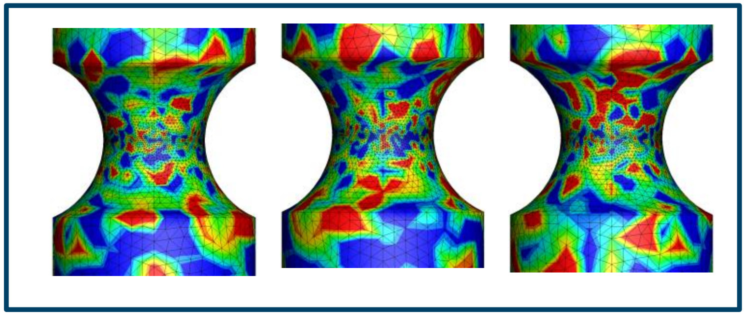


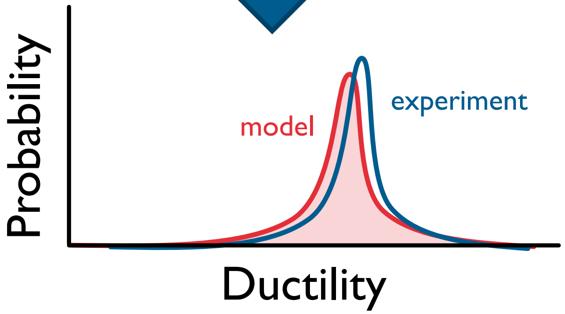


$$\text{Response} = f(microstructure, loading)$$

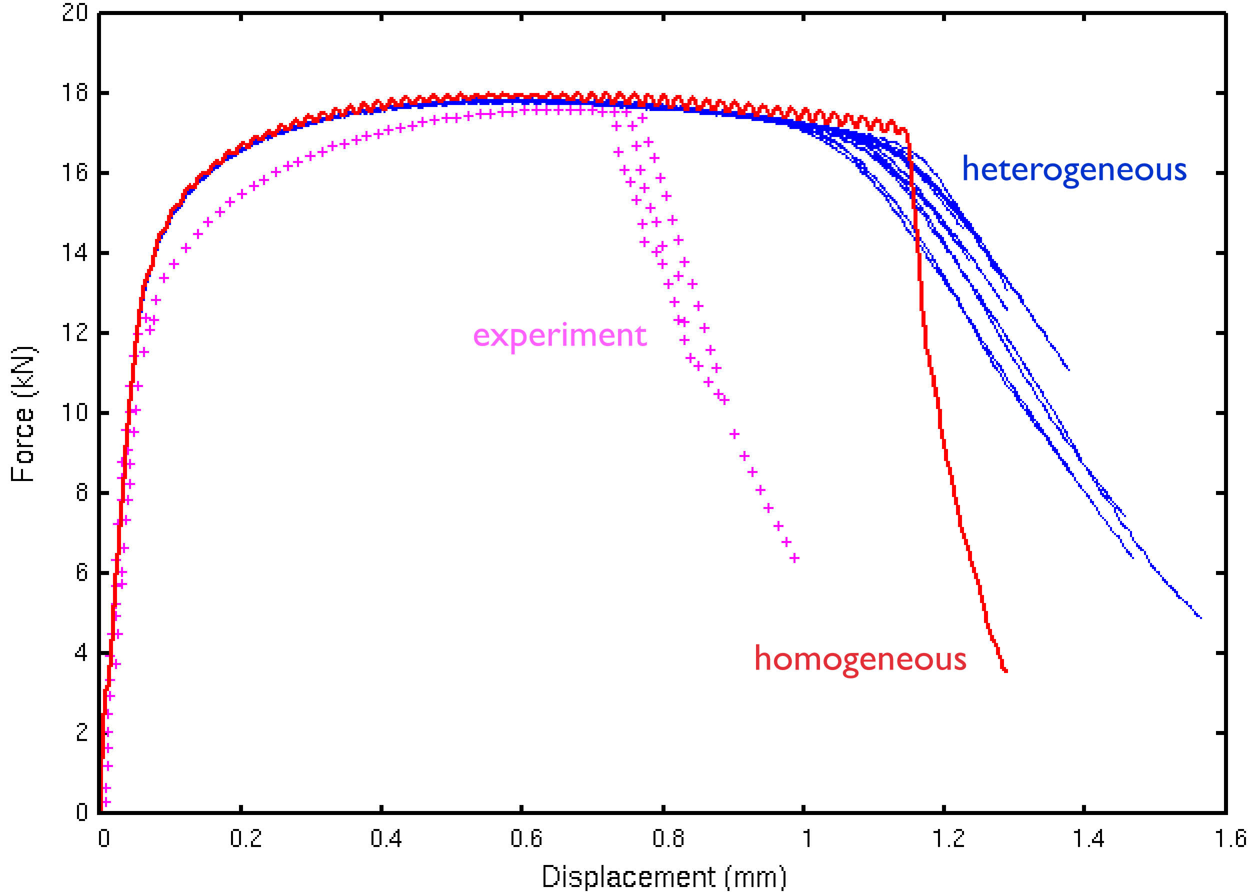


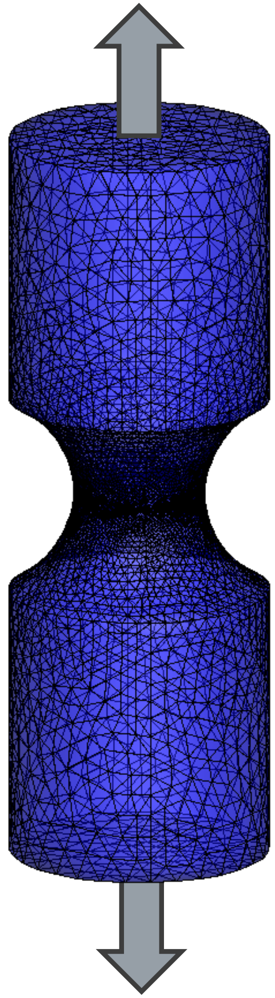






PRELIMINARY RESULTS





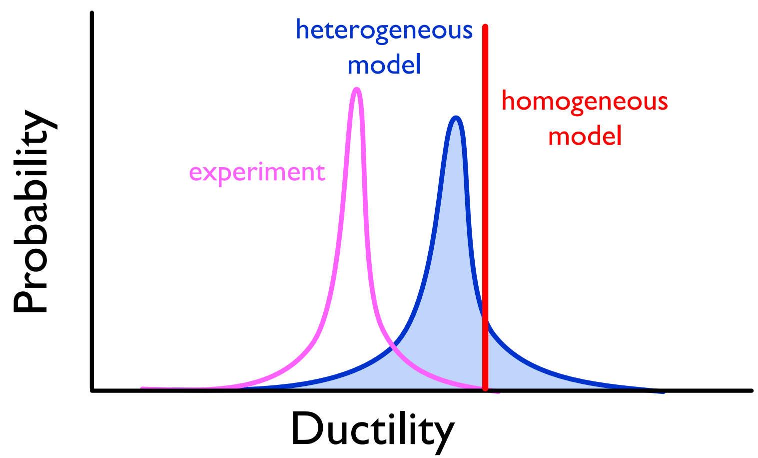
CLOSING REMARKS

- Failure initiation in a homogeneous material over predicts ductility

- Microstructural heterogeneity leads to macro-scale uncertainty

- Better statistics on microstructure (from observation rather than reconstruction) are needed

- Incorporation of more microstructural features could yield improvements



THANK YOU!

ARE THERE ANY QUESTIONS?